METHOD OF PRODUCING POWDER METAL PARTS

REFERENCE TO RELATED APPLICATIONS

This application claims an invention which was disclosed in Provisional Application Number 60/432,823, filed 12/12/2002, entitled "METHOD OF PRODUCING POWDER METAL PARTS". The benefit under 35 USC §119(e) of the United States provisional application is hereby claimed, and the aforementioned application is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention pertains to a method to produce a material from a metallurgical powder. More particularly, the invention pertains to a method of producing a material from a metallurgical powder comprising iron and carbon.

DESCRIPTION OF RELATED ART

Sinter hardening is a process used to produce a high martensite content material without using a conventional heat treatment process, such as batch heat treating or induction hardening. The sinter-hardening process comprises the steps of sintering the compacting at an elevated temperature, rapidly cooling the compact at the end of the sinter furnace to induce martensite transformation.

Another process that is commonly used in the field to produce power metal parts is double press double sinter (DPDS). In this process, a mixture of powder is compacted, pre-sintered, sized, put through high temperature sintering, and then heat treated. One problem associated with this process is that it is time consuming and high in cost.

Therefore, there is a need in the art for an efficient method of producing powder metal parts.

SUMMARY OF THE INVENTION

A method of producing parts from powdered metal comprising the steps of providing a metallurgic powder comprising iron, 0-1.5 weight percent silicon, 0.4-0.9 weight percent carbon, 0.5-4.5 weight percent nickel, 0.5-1.0 weight percent molybdenum, 0-0.5 weight percent manganese, and 0-1.5 weight percent copper, the weight percentages calculated based on the total weight of the powder. Next, the metallurgic powder is compressed at a pressure of 25 to 65 tsi to provide a green compact with a density if 6.4g/cc to 7.4g/cc. The compact is heated to a temperature of 2100°F to 2400°F for 20 to 60 minutes and held at 1000°F to 1900°F for 5 to 60 minutes. Then, the compact is selectively densified to greater than 7.6g/cc. The compact is heated again to 1650°F to 2100°F for 20 to 80 minutes and cooled at a rate of 150-250°F per minute.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows is a block diagram showing the steps of the present invention to produce powder metal parts.

Figs. 2a & 2b shows prior art temperature diagrams for annealing.

Figs. 2c & 2d show temperature diagrams for the method of the present invention for annealing.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method for producing powder metal parts with higher mechanical properties while having a minimum amount of heat distortion occur. The method is quicker and involves fewer steps than regular sinter and heat treatment as done in the prior art. Figure 1 is a block diagram that shows the method of producing powder metal parts. In the first step a mixture of metallurgical powder consisting of iron, 0-1.5 weight percent silicon, and 0.4-0.9 weight percent carbon are combined to provide a green compact. The metallurgical powder may further include other elements such as nickel in the range of 0.5-4.5 weight percent, molybdenum in the range of 0.5-1.0 weight percent, manganese in the range of 0-0.5 weight percent, and copper in the range of 0-1.5 weight percent, see Table 1.

Table 1

	Fe	C	Si	Ni	Mo	Mn	Cu
New Powder	Balance	0.4-0.9	0-1.5	0.5-4.5	0.5-1.0	0-0.5	0-1.5

The second step of the method is to compact the mixture of powders. The powders are compacted with a compaction pressure in the range of 25 to 65 tsi, resulting in a green density of 6.4 to7.4g/cc.

The third step of the present invention is to sinter the compact. Sintering is carried out in different ways based on whether the part being made will require high surface durability, high rolling contact fatigue, and/or high precision in profile, as shown in Figure 1. If high surface durability, high rolling contact fatigue, and/or high precision in profile is required then the parts need to be high temperature sintered, annealed, then selectively densified and sinter furnace hardened. In a preferred embodiment the above qualities are necessary and the green compact is sintered at a high temperature between 2100°F to 2400°F, preferably 2300°F. The compact is held at the high temperature between 20 and 60 minutes, preferably 40 minutes. Holding the compact at the sintering temperature for a sufficient time period is important to ensure that the individual alloy elements diffuse through out the compact.

Annealing of the compact takes place during the cooling step of the high temperature sintering. In the prior art, for example, in US. Patent No. 6,338,747, a method of producing powder metal parts uses a slow cooling step as shown in prior art Figure 2a. The slow cooling step is difficult to control. Prior Art Figure 2b shows the annealing step being present after the part has cooled down to room temperature. While this technique is acceptable it takes a significant amount of time and energy since the part needs to cool down to room temperature and then heat up to the annealing temperature.

In a first preferred embodiment, as shown in Figure 2c, annealing of the compact takes place during the cooling of the furnace directly after the high temperature sintering.

The compact is not allowed to cool down to room temperature, instead the furnace is allowed to cool down on its own, until the furnace temperature is about 50°F below the critical temperature of steel, which ranges from 1000°F to 1800°F. The compact is then held for 5 to 60 minutes at 1000°F to 1800°F for annealing to occur, improving the formability of the powder metal parts for densification. The cooling rate is not a factor in controlling the resultant hardness of the compact.

In an alternative embodiment, as shown in Figure 2d annealing occurs at the critical temperature. As in the previous embodiment, the furnace cools to the critical temperature at the cooling rate of the furnace. The compact is held at 1600°F to 1900°F for 5 to 60 minutes. Again, the cooling rate is not a factor in controlling the resultant hardness of the compact. The compact is then rapidly cooled. After annealing, the microstructure may be either mainly spheroidized Pearlite or mainly Pearlite. Annealing improves the formability of the powder metal parts for subsequent densification.

The next step of densification follows the annealing step of either embodiment and utilizes mechanical working or some other deformation technique to increase the density of all or a desired portion or region of the sintered compact to greater than 7.6g/cc. Examples of mechanical working include sizing, rolling, roller burnishing, shot peening or blasting, extruding, swaging and hot forming. Other techniques know to one skilled in the art may also be used.

The next step is sinter furnace hardening. The compact is held at 1650°F to 2100°F for 20 to 80 minutes and then cooled at a rate between 150 to 250 °F/min.

If there is no high surface durability and high rolling contact fatigue requirements, then annealing and densification is not necessary. The powder metal parts are high temperature sintered and then sinter furnace hardened. This sinter furnace hardening can be done separately from high temperature sintering or combined in the same cycle of high temperature sintering by adding a fast cooling device at the end of sinter furnace. The compact is then tempered at 300°F -1000°F for 30 to 90 minutes. The final microstructure is mainly tempered martensite, 0-20% bainite, and less than 5% retained austenite and the metal parts produced have a hardness of 27 to 50 HRC.

Example 1

A powder including 0.60 wt % carbon, 0.7 wt % silicon, 0.03 wt % chromium, 13 wt % manganese, 4.4 wt % nickel, and 0.85 wt % molybdenum was combined by blending, see Table 2. A green compact was formed by molding the powder between 25 to 65 tsi. The green density of the compact was 6.95g/cc. The green compact was then sintered at 2300°F for 40 minutes. In the next step the compact is sinter furnace hardened at 1850°F with fast cooling for 25 minutes. Lastly, the compact was tempered at 400°F for 60 minutes. The end product, a 25-teeth sprocket displayed an apparent hardness of 37 to 39 HRC and an overall tooth density of 7.07g/cm^3. The teeth of the sprocket were tested to see how much load may be applied before the teeth fail or rupture. In this example the test was conducted using three 0.200" diameter pins. The result was 7300 lbf to 8300 lbf in comparison to the same part by MPIF FN-0208 powder being made by the double pressed double sintered method and heat treated with induction hardening. The powder that was double press double sintered resulted in 5000 lbf to 6500 lbf being applied before tooth rupture occurred. By using the metallurgical powder and the method of the present invention, a higher tooth rupture strength was achieved even with a lower tooth density. The results are summarized in Table 3

Table 2

Powder	**Fe**	**C**	**Si**	**Ni**	**Mo**	**Mn**	**Cu**
New Powder	Bal	0.6	0.7	4.4	0.85	0.13	
MPIF FN-0208	Bal.	0.6-0.9		1.0-3.0			0-2.5

Table 3

Characteristic	**New Method**	**DPDS (Double Press Double Sinter)**
Powder	New powder with Si	MPIF FN-0208
Tooth Density	7.07g/cm^3	7.3g/cm^3
Tooth Rupture	7300-8300 lbf	5000-6500lbf

Example 2

A powder including 0.55 wt % carbon, 0.7 wt % silicon, 0.13 wt % manganese, 4.4 wt % nickel, and 0.85 wt % molybdenum was combined by blending as shown in Table 4. A green compact was formed by molding the powder between 25 and 65 tsi. The green density of the green compact was 6.95g/cc. The green compact was then sintered at 2300°F for 40 minutes. In the next step the compact is sinter furnace hardened at 1850°F with fast cooling for 25 minutes. Lastly, the compact was tempered at 400°F for 60 minutes. The end product, a 17-teeth sprocket displayed an apparent hardness of 38.5 HRC and an overall tooth density of 7.05g/cm^3. The teeth of the sprocket were tested to see how much load may be applied before the teeth fail or rupture. In this example the test was conducted using three 0.187" diameter pins. The result was 3353 lbf to 4353 lbf in comparison to the same part by MPIF FN-0208 powder being made by the double pressed double sintered method and heat treated with induction hardening. The powder that was double press double sintered resulted in 2473 lbf to3661 lbf being applied before tooth rupture occurred. By using the metallurgical powder and the method of the present invention, a higher tooth rupture strength was achieved even with a lower tooth density. The results are summarized in Table 5.

Table 4

Powder	Fe	C	Si	Ni	Mo	Mn	Cu
New Powder	Bal.	0.55	0.7	4.4	0.85	0.13	
MPIF-FN-0208	Bal.	0.6-0.9		1.0-3.0			0-2.5

Table 5

Characteristic	New Method	DPDS (Double Press Double Sinter)
Powder	New Powder with Si	MPIF FN-0208
Tooth Density	7.05g/cm^3	7.36g/cm^3
Tooth Rupture	3353-4353 lbf	2473-3661 lbf

Example 3

A powder including 0.60 wt % carbon, 0.7 wt % silicon, 0.13 wt % manganese, 4.4 wt % nickel, and 0.85 wt % molybdenum was combined by blending as shown in Table 6. A green compact was formed by molding the powder between 25 and 65 tsi. The green density of the green compact was 6.95g/cc. The green compact was then sintered at 2300°F for 60 minutes. In the next step the compact is sinter furnace hardened at 1850°F with fast cooling for 25 minutes. Lastly, the compact was tempered at 400°F for 60 minutes. The end product, a 26-teeth sprocket displayed an apparent hardness of 40 HRC and an overall tooth density of 7.06g/cm^3. The teeth of the sprocket were tested to see how much load may be applied before the teeth fail or rupture. In this example the test was conducted using three 0.187" diameter pins. The result was 4740 lbf in comparison to

the same part by MPIF FN-0208 powder being made by the double pressed double sintered method and heat treated with induction hardening. The powder that was double press double sintered resulted in 806 lbf being applied before tooth rupture occurred. By using the metallurgical powder and the method of the present invention, a higher tooth rupture strength was achieved even with a lower tooth density. The results are summarized in Table 7.

Table 6

Powder	**Fe**	**C**	**Si**	**Ni**	**Mo**	**Mn**	**Cu**
New Powder	Bal.	0.6	0.7	4.4	0.85	0.13	
MPIF-FN-0208	Bal.	0.6-0.9		1.0-3.0			0-2.5

Table 7

Characteristic	**New Method**	**DPDS (Double Press Double Sinter)**
Powder	New Powder with Si	MPIF FN-0208
Tooth Density	7.06g/cm^3	7.36g/cm^3
Tooth Rupture	4740 lbf	806 lbf

In producing metal parts using the methods described above, the tooth density of the metal parts produced may vary with compaction pressure and powder compressibility, making the range of tooth density produced using the methods of the present invention between 6.75g/cc to 7.25g/cc.

Accordingly, it is to be understood that the embodiments of the invention herein described are merely illustrative of the application of the principles of the invention. Reference herein to details of the illustrated embodiments is not intended to limit the scope of the claims, which themselves recite those features regarded as essential to the invention.